E/CONF.39/A/342
6 Nov.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item : A. 3. 1. 2

United States of America

EDUCATION IN HYDROLOGY

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No. 687

A.3.1.2

EDUCATION IN HYDROLOGY

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1. The growing importance of development and intelligent management of water supplies for mankind has created an urgent world-wide need for scientifically trained hydrologists.

2. In recent years, many water problems are being amplified by a rise in man's standard of living, increased production of food and industrial products, and settlement of previously undesirable regions. Thus, water problems are directly related to such things as: (1) increase in population, (2) geographic shifting of population centers, (3) more water use per capita, (4) deterioration of watersheds and a decrease of perennial water, (5) pollution of streams and lakes by man's wastes, and (6) occupation of semi-arid regions.

3. But the water challenge is not limited to desert areas. Intensive development in certain areas where water is plentiful has created severe problems. Supplies adequate in past years are no longer usable. Man's occupation in certain watersheds has increased destruction by floods; sediment from increased erosion clogs drainageways; streams and lakes are polluted by industry and cities. In some areas, inadequate drainage and increased salinity have brought about the loss of arable lands.

4. Many of these problems caused by man cannot be solved by the mere application of money, concrete and labor. Throughout the world, sheer lack of knowledge, of understanding, still impedes the making of sound water development plans on a scientific basis. As the competition for known water supplies becomes ever more keen, the deficiency in basic knowledge of hydrologic principles becomes progressively more serious. Today, in the resolution of late-stage water developments, the margin of error permissable in initial stages cannot be tolerated.

5. The production of well-trained hydrologists, therefore, must have high priority throughout the world, if man's hope of obtaining optimum benefit of the water resources available is to be fulfilled.

6. In this effort, colleges and universities have an indispensable role to play, because the kind of broad education needed can be efficiently given only by them, and because of their traditional interest in basic aspects of the sciences. As hydrology is an interdisciplinary science, it requires the talents and skills of a variety of fields. The water specialist must be well trained in mathematics, physics, chemistry, meteorology, geology, hydromechanics, and agricultural sciences. In addition, he must have a knowledge of economics, social sciences, and law. The training of such persons presents difficult problems to the educational institution attempting to design appropriate programs.

7. The importance of research and advanced training cannot be overstressed. Much necessary insight is still to be gained in the many processes of the water cycle. The attraction of talented students to rigorous training programs requires substantial financial assistance; otherwise, the objectives cannot be attained. As many nations experiencing problems in water resources do not have trained hydrologists or educational facilities, international as well as national programs are essential.

8. Furthermore, international cooperation in promoting knowledge of water resources is called for by the very nature of the subject. As R. L. Nace of the U. S. Geological Survey states in his discussion of "A Plan for International Cooperation in Hydrology":1/

> No nation occupies an entire continent. (The subcontinent of Australia is an imperfect exception). No continent has a closed hydrologic system, but each is a part of a global system. Therefore, no nation can learn by itself, within its own boundaries, all that it must know about water and the hydrologic cycle. None can completely learn even its own local water balance within the continental system...Cooperation among nations is required, so the task is international.

THE SCOPE OF THE SCIENCE OF HYDROLOGY

9. The science of hydrology promotes sound economic development by making possible a realistic understanding of man's hydrologic environment. There are many concepts and definitions of hydrology, but one most suitable for our purpose is from Scientific Hydrology, 2/

> Hydrology is the science that treats of the waters of the Earth, their occurrence, circulation, and distribution, their chemical and physical properties, and their reaction with their environment, including their relation to living things. The domain of hydrology embraces the full life history of water on the Earth.

10. Under this broad definition, the science includes understanding of the earth's physical features and the mechanics of its atmospheric systems. Man's social and economic requirements for management of water resources are to be related to the total hydrologic environment.

11. An adequate description of the global water cycle is still needed to define the circulation of water on the earth as a whole. The nucleus of hydrology lies in the earth sciences. The unifying concept is the hydrologic cycle. The cycle begins and ends with the world ocean and involves the transport of water from sea to air, and from air to land. Here, it may be stored for short or long periods, after which it moves in surface streams or through the earth's porous rocks as ground water back to the sea. In this transitional movement, water passes through the gas, liquid, and solid states. It leaves the sea essentially pure, but during its transit dissolves many inorganic and organic compounds as it passes through one or several biological systems. Further, it erodes the earth's rocks, changes the continental profile, and returns to the sea laden with many minerals and with man's wastes. The quantitative water budget of the oceans and continents, and the dynamics of water vapor in the atmosphere, need to be better understood. The horizontal transport of water vapor in the atmosphere as well as the precipitable water must be evaluated to obtain the net influx of water vapor to areas of water need. The water balance of the globe requires more attention than heretofore for the sake of better understanding of the terrestial phase of the hydrologic cycle.

12. There still are major gaps in the basic data necessary to adequately explain the distribution of water on the globe. For example, the magnitude of the North

African aquifer is not known, and as yet no discharge measurements have been made on the Amazon, the world's largest river. There are vast desert, tropical, and polar regions of variable climate for which there are no hydrologic data. Such regions are of tremendous significance for a global analysis of the water budget.

13. As a complement to these physical and biological aspects, the hydrologist should have knowledge of factors that bear on water management. Comparative and quantitative studies of water management techniques, as influenced by climatic variability, water distribution, land use, and economics, are called for. Legal, social and ethnologic characteristics have a large bearing on the devising of acceptable water projects for mankind. Historically, hydrology has been more empirical than theoretical, but the time has come when hydrology must become fully a science.

RECENT DEVELOPMENTS IN HYDROLOGY EDUCATION IN THE UNITED STATES

14. The world over, many programs for improving economic and social conditions hinge on water resources. But the skills to design and manage proposed projects fall far short of the growing demand for them. In the United States, also, despite a long concern for progressive water development, the supply of trained men is inadequate in many respects. In the last several years, many scientists, and governmental agencies in the water field, both state and national, have expressed concern. Only a few educational institutions in the United States have long experience in offering some basic courses in hydrology, which comprise the formal academic training of today's senior hydrologists. Prior to 1960, less than 60 major universities listed hydrology courses in their catalogs and only 14 of these were offered at a graduate level. A special panel on the matter of training reported that, as of 1960 -- there were perhaps only five or six universities which offered anything approaching a program of advanced study in hydrology.

15. In August, 1962, an Inter-University Conference on Hydrology was convened by the University of California, Los Angeles, w/representatives from nineteen universities, eight federal (national) agencies, and the American Geophysical Union. The participants were of unanimous opinion that there is a critical shortage of suitably trained men in all aspects of hydrology and that universities are obligated to develop adequate educational programs. The group also agreed that much more research in the water field at universities is needed to strengthen training programs at the graduate (advanced) level.

16. But even before the Conference expressed this consensus, some half-dozen universities had announced broader programs in hydrology for the 1961-1962 academic year. Most of them are designed for graduate training, and are interdisciplinary in that courses of instruction offered by several departments are integrated. The programs differ somewhat depending upon the advanced degree; the degrees given are usually in a specific departmental area. New techniques in statistics, operations research, and systems engineering are some of the powerful tools which are now being taught. (One university in the southwest, the University of Arizona, offers both undergraduate and graduate degrees in hydrology. An incomplete survey of the courses now being offered in colleges and universities in the United States in given in Annex B.) Requirements for entrance to these programs include substantial background in mathematics, physics, chemistry, hydro-mechanics, and geology.

17. In the academic year 1962-63, other American colleges and universities began to integrate course offerings in the broad field of water resources. Thus, there are now about 20 institutions in the United States which are striving to make hydrology, as a scientific discipline, comparable to other physical sciences. Most of these are state universities located in the western half of the country; others are in the "Middle West" and the coastal areas of the east. This recent intense effort, which benefits from active cooperation among universities, is a significant development in education.

TRAINING FOR STUDENTS OF OTHER NATIONS

18. Many students from other nations are already studying hydrology and related fields in the United States. With the growth of the newer programs described above, more opportunities are becoming available to students from abroad.

19. The study of hydrology, a science that is literally global in scope, calls for international exchange of knowledge regarding one of man's essential resources. Improved educational and training facilities, in the United States as in other countries, will contribute to the better solution of water problems throughout the world.

Annex A. Study in Hydrology and Related Fields at the University of Arizona

20. To provide an integrated program in hydrology in American universities usually requires special interdepartmental arrangements. The experience of the University of Arizona is of interest.

21. This University initiated in 1961 a new program in scientific hydrology which provides broad training in basic sciences and a rigorous synthesis of hydrologic systems. The program includes undergraduate and graduate curricula leading to Bachelor of Science, Master of Science, and Doctor of Philosophy in Hydrology. It includes basic courses in mathematics, physics, chemistry, geology, meteorology, hydromechanics, botony, economics, and social sciences.

22. Eight new hydrology courses at the graduate level deal with scientific principles and systems analyses of the many hydrologic interrelationships. The graduate program is open to students holding degrees in other fields such as civil engineering, geology, soils, meteorology, and agriculture. Prior study in hydrology is not required provided certain requirements are met: Differential equations, general chemistry and physics, physical and historical geology, fluid mechanics, botany or biology, economics, engineering drawing and data analysis, field techniques, surveying and geologic mapping.

23. The hydrology program is guided by a committee of representatives from the participating departments. The committee, acting in lieu of a departmental faculty, recommends acceptance or denial of applications, advises students, develops and approves graduate study programs, approves research topics and directors, and suggests examining committees.

24. In connection with this new program, it is also of interest to mention some other significant activities of the university which concern water resources.

25. The University of Arizona has achieved a recognized position in arid land and water studies owing in part to its location in the arid southwest. Emphasis on teaching and research in hydrology naturally varies from department to department but the exceptional scope of the University's work in this and related fields is seen in activities outlined as follows:

26. The Institute of Atmospheric Physics conducts research in behalf of basic knowledge of the weather and climate of Arizona, of the southwest, and of arid regions of the earth in general. The Institute views the problem of water in an arid land as the fundamental one, and studies aspects such as the regional flux of water vapor, microphysical properties of water particles in the clouds, etc.

27. Many studies relating to water are done in the College of Agriculture. The Department of Agricultural Engineering has collected over many years material of exceptional significance for hydrology, such as full historical records of ground water basins. Closely related to this work is the determination of transmissibility and specific yield of water bearing formations.

28. The Institute of Water Utilization is involved in fundamental and applied research relating chiefly to development, conservation and utilization of water resources under semi-arid and arid climatic conditions. A major subject of research is artificial recharge, related to the ground water supply in Arizona. The Department of Watershed Management is concerned with methods for wildland watersheds which will produce optimum yields of water and other products coincident with satisfactory flood and erosion control. Investigations of transpiration rates of various plants are being made with the aim of manipulating vegetation for maximum water yield.

29. Soil water and water quality are the special concern of the Department of Agricultural Chemistry and Soils. The Department is also conducting research into the movement of water and nutrients through soil and into plants.

30. The Department of Agricultural Economics deals with such matters as the pricing of water, the patterns of watershed development and land use, structures of water law, and water regulatory organization.

31. The interests of the department of Civil Engineering lie in conception, design, construction and operation of water development projects. Recent research includes the hydraulics of long culverts and of partially full flow in conduits of various shapes.

32. The Geochronology Laboratories studies some problems to do with occurrence and movement of water during geologic history.

33. The Laboratory of Tree-Ring Research is an important supporting unit for the hydrology program, with its studies on the relation between environmental parameters and the radial growth of trees. There are strong indications that variations in width of tree-rings reflect variations in precipitation and streamflow during the past 5,000 years.

REFERENCES

1. A Panel of Hydrologists (U.S.A.), A Proposal and Plan for International Cooperation in Hydrology, Bull. Inter. Assoc. Scien. Hydrol., p. 11, v. 6, (1961)

2. Ad Hoc Panel on Hydrology, W. B. Langbein, Chairman, Scientific Hydrology, Federal Council for Science and Technology, Washington, D.C. (June 1962).

Annex B:

Titles of courses in hydrology and closely related areas offered by educational institutions in the United States.

Dealing chiefly with physical factors

*Hydrology
Groundwater hydrology
*Surface water hydrology
*Field hydrology
*Land mass hydrology
*Watershed hydrology
*Hydrologic systems
*Dynamics of flow systems of the earth
*Quantitative determination of aquifer performance
*Geology of groundwater
*Fluid mechanics
*Hydrodynamics
Flow in porous media
Free surface flow
*Hydraulics of open channels
*Hydraulic engineering
Flood control hydrology
*River hydraulics
Water power engineering
Coastal engineering
River-harbor engineering and hydraulics
*Irrigation hydraulics
Drainage of agricultural lands
Seepage and earth dams
*Meteorology
Hydrometeorology
*Physical and dynamical meteorology
*Physical climatology
*Arid zone agroclimatology and micrometeorology
*Physics of soil water
Glacial geology
Permafrost
Fluvial geomorphology
Hydrodynamics of sediment transportation
Limnology
Oceanography
*Water quality and geochemistry
*Quantitative geomorphology
*Analog model analysis of hydrologic systems
*Statistical hydrology
Applied statistics in hydrology
Application of digital computers to hydraulics and sanitary engineering problems

Dealing chiefly with biological factors

*Forest influences on watershed management
*Plant-water-soil relationships
*Dendrohydrology
Hydrobiology
*Water supply and waste water disposal
*Principles of sanitary engineering
Water pollution control
Chemistry of water purification and sewage treatment
Atmospheric pollution
*Industrial wastes
Disposal of radio-active wastes

Dealing chiefly with economic and social factors

*Water utilization
*Appraisal and development of water supplies
Principles of watershed management
*Watershed programs, administration and policy
Wildland hydrology
*Irrigation management and water conservation
Water institutions and economics
Economics of water resources
*Water law
Human ecology
*Land economics

*Courses offered in hydrology programs at the University of Arizona, Tucson.

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